THE
LUCIUS BEEBE
MEMORIAL
LIBRARY
WAKEFIELD
MASSACHUSETTS

THE GEOLOGY OF WAKEFIELD, MASSACHUSETTS.

By

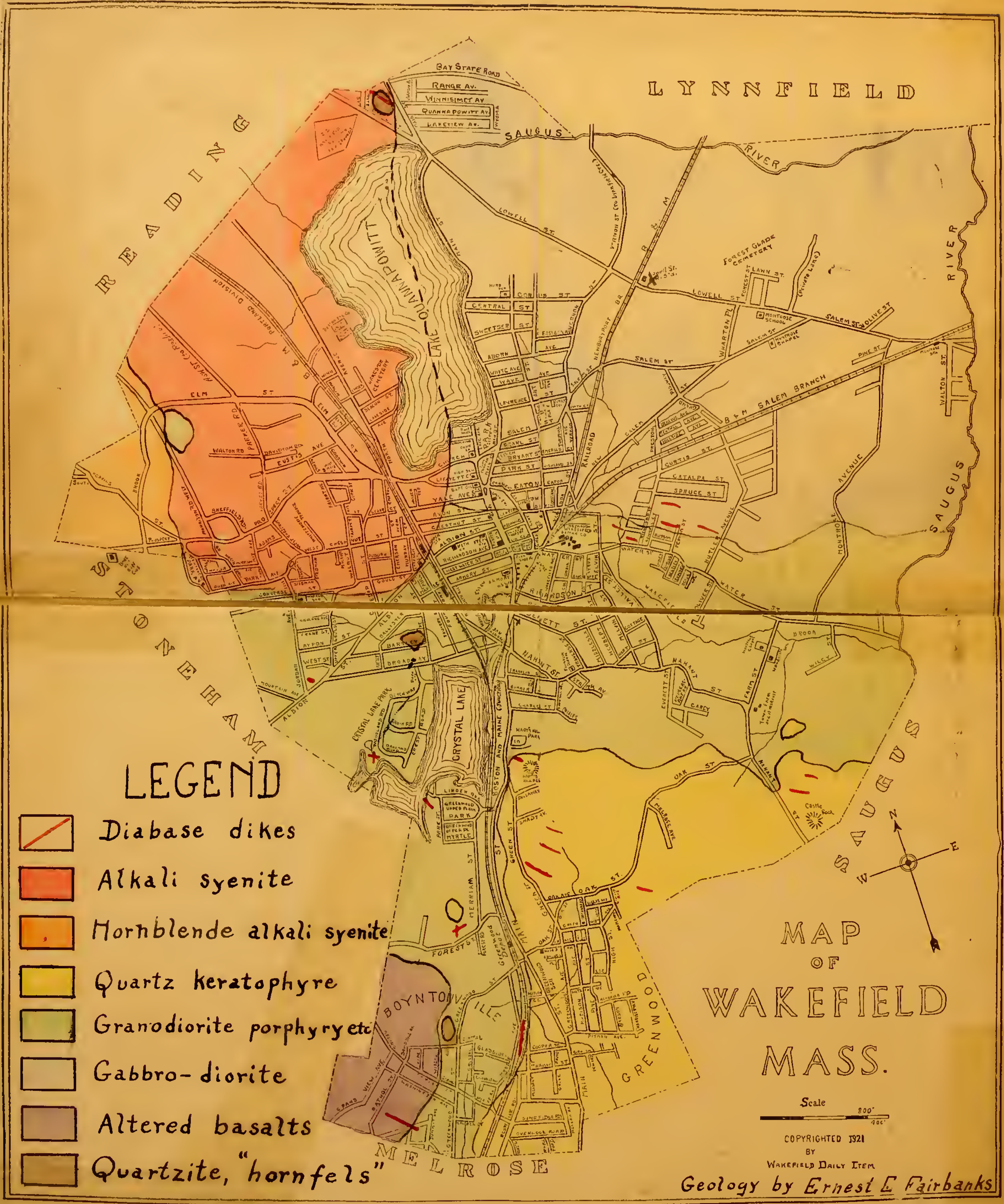
Ernest E. Fairbanks.

-1922-

G.C.
974.4
WAKEFIELD

32340

32340



MAP OF WAKEFIELD MASS.

LEGEND

╱	Diabase dikes
🟥	Alkali syenite
🟧	Hornblende alkali syenite
🟨	Quartz keratophyre
🟩	Granodiorite porphyry etc
⬜	Gabbro-diorite
🟪	Altered basalts
🟫	Quartzite, "hornfels"

COPYRIGHTED 1921
BY
WAKEFIELD DAILY ITEM

Geology by Ernest E Fairbanks

THE GEOLOGY OF WAKEFIELD, MASSACHUSETTS.

Table of Contents

Part I

Introduction

1. Purpose of the Report Page 1
2. Petrography 1
3. Age of Rocks 5
4. Early Carboniferous Flows 6

Part II

Acknowledgments 9

Petrography 10

Structural Geology 16

Table of Formations 18

Historical Geology 19

Map

Glossary

1. Minerals 21
2. Technical Terms 23

Bibliography

1. Articles Cited 25
2. General Geology 25
3. Petrography 25
4. Mineralogy 26

INTRODUCTION

The geology of Wakefield was undertaken by the writer in connection with a course in petrography completed at the Massachusetts Institute of Technology during 1921-1922. It was with considerable surprise that the area covered was found to be so little known geologically. It is the writer's desire to correct certain statements, especially in regard to faulting, which have appeared in print. [2] (See bibliography at end of paper.) No claim is made as to the completeness of this work, but it is believed that the considerable new data should be made available.

In order that this paper may not be entirely unintelligible to readers not especially versed in the study of earth features a short introduction has been prepared to a number of the features presented in the more technical Part II.

Persons in all trades and callings necessarily use words that apply only to their work and that are therefore technical. The simpler the subject or the more superficially it is treated the fewer are the technical terms used, but most ordinary occupations have such terms. Farmers, for instance, "list" corn and "drill" wheat. Terms of this nature encountered in the paper may be found in a glossary at the end divided into two sections, minerals and technical terms.

A somewhat extended bibliography is also included for the convenience of any who would delve further into the ways of nature.

PETROGRAPHY.

Petrography is the description of rocks with the aid of the microscope. The microscope employed in petrography is of a special type by means of which certain phenomena of light applied to minerals aid in their identification. We do not ordinarily think of light as being able to pass through the minerals which make up a rock. Light will pass through the minerals, however, providing they are of sufficient thinness, about 1/1000 of an inch, so thin that print may be read through them. About a hundred such thin sections were prepared of Wakefield rocks.

To understand the manner in which the descriptions of these sections were made it is necessary to review a few facts concerning light. Light travels by means of motion of the ether in a manner which has often been compared to waves in water moving in all directions away from a point of disturbance. The form of this wave motion is shown in figure 1.

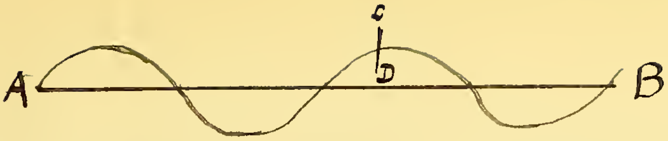


Fig. 1.

A - B represents the direction of transmission or propagation. Ordinary light vibrates in all planes at right angles to this direction of transmission; for example, C - D shown in figure 2.

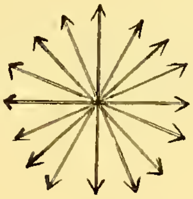


Fig. 2.

There are some minerals in which light would vibrate similar to ordinary light. The majority of minerals are of a different nature and produce vibrations known as plane polarized light. The very common mineral calcite illustrates this phenomenon very well.

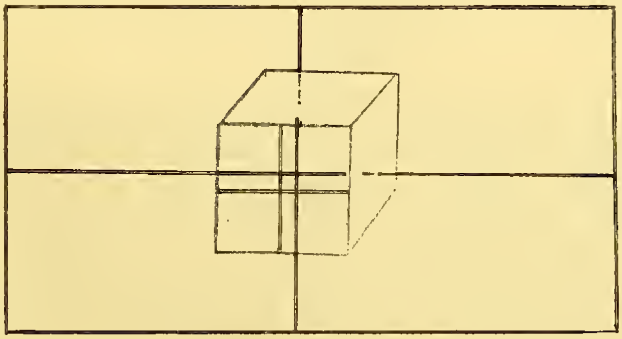


Fig. 3.

Figure 3 shows calcite placed over a card marked by two lines. Each of these lines appears double. The light after

entering calcite no longer possesses the form of ordinary light but becomes plane polarized, that is it vibrates in but one plane (figure 4) and becomes divided into two rays of light known as ordinary and extraordinary rays vibrating in one plane and at right angles to each other.

Fig. 4

Now we can follow the light in its passage through the petrographic microscope. In order to simplify matters the lenses are not shown.

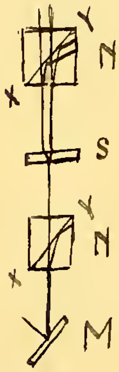


Fig. 5

Ordinary light strikes the mirror (M) and is reflected to a calcite prism known as a nicol prism. This is calcite cut along the line X - Y and recemented. The light upon entering the nicol (N) is broken into two rays, ordinary and extraordinary, one of which, the ordinary, is lost by reflection from the cemented surface (X-Y). The extraordinary ray passes through the nicol now as plane polarized light and enters a mineral in a thin section (S) and is broken into ordinary and extraordinary rays. Each of these two rays are again divided into two rays on entering the second nicol (N′) and the two ordinary rays are lost by reflection as at first. We have passing through the section two rays which vibrate in the same plane (figure 4) but one is slower than the other according to the amount which the mineral at S has divided them. These two rays interfere with each other producing a color known as an interference color. Two rays interfering with each other would appear as in figure 6.

Fig. 6

If we know the thickness of the section, as we would by observing the color of a known mineral, the interference color will aid us in the identification of the mineral.

Reference will be also noted to extinction, another important factor in mineral determination. When we have our nicols arranged as in figure 5 and turn our section around, (the stage is constructed so as to permit rotation,) positions will be found where the color disappears and the section remains dark.

The dark position is the extinction position. There is one direction, and often two, through a mineral along which light does not become plane polarized, in other words only ordinary light is transmitted and the section appears dark. In a certain class of minerals (isotropic) all directions transmit light equally and it does not become divided (refracted) so that light entering continues to possess the vibrations of ordinary light. It can be plainly seen that with our nicols both in position, a section of this nature would remain dark during a complete rotation of the section.

There are numerous other determinations besides those given above, which, taken together serve to establish the identity of the mineral under question. This optical analysis serves to identify with considerable accuracy in regard to the chemical composition and as more data is collected its efficiency will become increased.

Everyone is interested in the applications to industry of scientific subjects. At one time the attempt was made to draw a line hard and fast between what was called "pure" science and "applied" science. As practically all "pure" science eventually finds application, even within our day, the attempt proved very difficult or impossible to define what should fall in one class and what in the other.

Fossils were at one time considered one of the shining examples of "pure" science but today they have become of prime importance in the search for "liquid gold" or petroleum.

Petrography finds its applications more and more to everyday life. Following are a few examples which may serve to demonstrate its usefulness.

1. The valuation of an ore deposit and its probable extension in depth are determined.

2. Throughout every branch of the ceramic industry.

3. Solving fault problems. Here the ore suddenly terminates against a wall, the fault surface, and the ore has gone somewhere in 360°. Sometimes geological criteria serve to fix the direction but more commonly it is impossible to do so. Thin sections have been used to advantage to solve the direction of movement.

4. Structure, of prime importance in the search for oil, has often been solved.

5. It is proving itself indispensable to the chemist as an optical analysis often requires but a small fraction of the time necessary for a chemical analysis.

AGE OF ROCKS.

There are many ways of determining the relative age of igneous rock bodies. On some, thin sections give us the information. If a rock cuts through another the rock cut must necessarily have been there first in order to have been cut. In the case shown in figure 7, the texture of A becomes finer toward B showing that it has been chilled by B and that A is the younger.

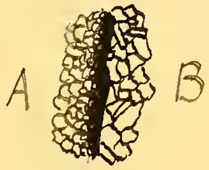


Fig. 7

A volcanic rock which pours out over the surface is, of course, younger than its basement rock.

Figure 8 gives an example similar to one described in Part II under Historical Geology.

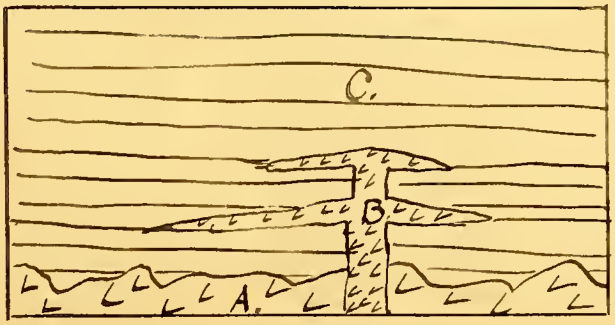


Fig. 8

The age of the sediments, C, is known from the fossils which it contains. A is older than C because it forms the basement for C. A is similar in nature to B but A is older as B cuts it. B consists of surface flows showing that they poured out over the surface of the lower part of C so are younger than lower part of C. B was covered by the upper part of C so is older. Later another flow of B spread out over another later surface. The different flows of B and the sediments C were formed at the same general time, the age of the fossils which C contains.

EARLY CARBONIFEROUS FLOWS.

The fact that Wakefield has been the scene of volcanic activity in the dim past of geologic history may come as a surprise to some not especially interested in geology. We associate volcanoes with Southern Italy and the Hawaiian Islands, but hardly with staid New England.

The rock which forms Hart's Hill and Castle Rock, as well as a considerable portion of Wakefield as can be seen from the map, flowed from some ancient vent during that period in the earth's history characterized by extensive forests and vegetation which at present form the coal of Pennsylvania. This rock not only developed quietly, as at Hawaii, but much of it represents eruptions of a much more violent nature. These ancient volcanic rocks do not retain much of their original character but devitrify same as old cut glass ware changes. The microscope reveals the original character as sufficient evidence of the original textures are preserved.

Photomicrograph of pyroxenite from Ketchikan, Alaska. (Copied and enlarged from photo by C. P. Berkey by the writer.) Taken with plain light magnification about 46 diameters.

The light gray mineral is calcite, the black streaks through it are leucoxene. The rest of the field is pyroxene and epidote. The epidote is almost entirely distributed through the pyroxene.

The courses of the leucoxene are so true as to indicate development along some original structure like a cleavage, but it does not agree at all with the calcite cleavage. It is believed, from this evidence, that the calcite replaced some original mineral, presumably ilmenite, as leucoxene is a very common secondary product derived from ilmenite.

Photomicrograph of altered porphyry, 1460 feet south of Daly-West shaft on the 300 foot level, Judge Mining & Smelting Co., Park City, Utah. (Collected, prepared, and photographed by the writer) Taken with plane polarized light. Magnification 80 diameters.

This is a very interesting section as the rock has been completely altered and mineralized. The large black minerals with regular crystal outlines, and the finer disseminated black minerals, are pyrite. This process of alteration is known as sericitization and the specimen from which the section was prepared had an appearance not unlike ordinary chalk with tiny pyrite crystals disseminated throughout.

PART II

ACKNOWLEDGMENTS.

Words fail to adequately express the writer's appreciation of the patient instruction in petrography by Dr. Charles H. Warren, formerly of the Massachusetts Institute of Technology, which made this paper and others possible.

His thanks are also due to Mr. R. E. Head of the United States Bureau of Mines, Salt Lake City, Utah, for instructions in the preparation of thin sections and to Dr. John E. Wolff of Harvard University for permission to use the laboratories in their preparation.

PETROGRAPHY

QUARTZITE F-115

DISTRIBUTION: The areas occupied by the quartzites are small as will be seen from the map. The largest area occurs at the northern end of Lake Quannapowitt on Main Street. With the quartzite north of High Rock in Greenwood are associated some "hornfels."

MEGASCOPIC: Medium greenish gray rock of fine grain. Quartz is the only mineral distinguishable, but the individual grains cannot be distinguished.

MICROSCOPIC: The quartz occurs as roughly equi-dimensiohal grains and as elongated grains. The quartz grains vary greatly in size from very minute anhedra, occuring between the larger grains, as developed by crushing, to grains .29 mm. x .24 mm., and in elongated forms .78 mm. long x .18 mm. in width. There are, apparently, about the same quantity of grains of all dimensions with the exception of the largest sizes.

Considerable albite occurs possessing good twinning after the albite law and is quite free of alteration.

Actinolite occurs arranged interstitially between quartz anhedra. Considerable iron ore, zircon, apatite, rutile and limonite are present.

BASALT F-100

DISTRIBUTION: The altered basaltic volcanics occupy considerable area in Greenwood. They extend from High Rock, Greenwood-Melrose line, north nearly to Greenwood Hill. Agglomerates containing fragments of "hornfels" occur near the northern end and on the west slope of High Rock[3].

MEGASCOPIC: The rock is light gray to light green sometimes dark gray on fresher surfaces. The light green is due to the extensive production of epidote during alteration. The surface is commonly amygdaloidal with pillow structure. Later basaltic dikes as well as the numerous diabase dikes cut this rock.

MICROSCOPIC: The freshest rock possessed a fine grained ophitic texture. The feldspar laths are between andesine and labradorite. The groundmass consists of a fine grained aggregate of feldspar rendered nearly opaque with magnetite dust. The alteration products are muscovite (sericite) and chlorite. Other sections are largely obscured by abundant epidote.

Gabbro-dorite (Salem gabbro-diorite) F-55

DISTRIBUTION: The gabbro-diorite occurs north of Water Street as stringers cutting the granite for a distance of a quarter of a mile or less. Further north the granite does not appear and the gabbro-diorite is continuous into Lynnfield.

The gabbro-diorite has been well described and will not be described here.[2]

GRANODIORITE PORYPHYRY F-134

DISTRIBUTION: The granodiorite porphyry extends north from High Rock, west of the railroad to a point about one quarter of a mile north of Crystal Lake. It assume a non-porphyritic appearance in the vicinity of Water Street north of Castle Rock eastward into Saugus.

MEGASCOPIC: Dark gray porphyritic rock with feldspar phenocrysts in a fine grained groundmass containing abundant biotite. The grain is medium.

MICROSCOPIC: The phenocrysts are chiefly Oligoclase (maximum extinction 8°). There is some orthoclase and a little microperthite was observed. The feldspar and quartz form a graphic intergrowth (not abundant). Quartz forms about 6% of the rock. Abundant hornblende, some pyroxene, titanite, and apatite are present.

SHEARED GRANODIORITE PORPHYRY F-131b

DISTRIBUTION: Occurs south of foundry beside the railroad. There is a sharp boundary between the sheared granodiorite and the normal granodiorite.

MEGASCOPIC: Medium bluish gray rock characterized by abundant phenocrysts of feldspar usually as elongated forms, also well rounded, with the dark constituents wrapped around them. The feldspar has been considerably altered as shown by its milky color. The minerals of the groundmass could not be distinguished with the exception of a small amount of disseminated pyrite.

HORNBLENDE ALKALI SYENITE F-69

DISTRIBUTION: The hornblende alkali syenite is exposed near the Wakefield-Stoneham-Reading boundary lines, especially on Elm Street, the southern extremity of Bear Hill, and westward into Reading. Its outcrops were followed west to the State Highway in Reading a distance of one and one-half miles from the Elm Street exposure in Wakefield.

MEGASCOPIC: Dark gray rock varying from fine grain to coarse grain. The coarse grained type consists of abundant black hornblende and biotite, feldspar, some in twinned laths, and disseminated pyrite. The more altered specimens contain a greater amount of biotite than the fresher material. This rock strongly resembles the hornblende syenite of Arlington Heights although no material was found as coarse in grain as that type.

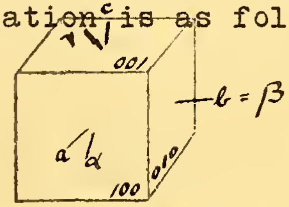
MICROSCOPIC: The minerals consist of hornblende, feldspar, biotite, magnetite, apatite, pyrite, and the alteration products, kaolin and sericite. The volumetric percentages were determined as Hornblende (with some biotite) 57%, Feldspar 43%.

HORNBLENDE: The orientation of the hornblende was obtained by the following method; A section was found cut exactly normal to an optic axis, this gave the directions of γ and β The pleochroism was then obtained for these directions and found to be:

γ = Deep greenish brown
β = Deep greenish brown

γ is very near or equal to β.

The pleochroism was then found across the obtuse cleavage angles on a basal section (direction of a). This color was found to be a light yellow hence neither γ or β and therefore α . The optic normal section was found to possess a single cleavage and as α had been determined near a, the section was referable to (010) rather than to (100). The extinction on (010) amounted to 20° so the orientation is as follows:



The hornblende is a soda-rich type not referable to the barkevikite variety and is probably one of the katophorites. The hornblende and biotite occur throughout the slide with a tendency to form aggregates in which the biotite and hornblende are intimately associated. Rarely the hornblende surrounds a core of colorless pyroxene. These aggregates are characteristic of a number of local rocks such as the Essexite of Salem Neck and dikes of Manchester, Mass. They were probably formed during a late stage of the consolidation of the rock magma, a change referred to as deuteric (Sederholm 1916), paulopost (Evans 1916) or penecontemporaneous 6. This structure could have also been produced by the action of pneumatolytic varpors from a later intrusion.

Feldspar: Albite appears to be the most abundant feldspar.

QUARTZ, KERATOPHYRE F-71

DISTRIBUTION: The quartz keratophyre is the rock most resistant to erosion in the area. Hills with an elevation of about 260 feet consisting of quartz keratophyre are numerous. Their nature can be told at a glance from some distance by their light color. Hart's Hill and Castle Rock consist of this rock.

MEGASCOPIC: Fresh surfaces are dark, somewhat greenish, black. The weathered surfaces are light, slightly bluish, gray to nearly white. Phenocrysts of feldspar are distinguishable.

MICROSCOPIC: The phenocrysts consist of oligoclase. A section normal to (010) (symmetrical zone) gave a maximum extinction of 8° and determinations of the refractive indices by the immersion method also indicated this feldspar. There is also some microcline-albite microperthite, the microcline being untwinned. The feldspar is strongly kaolinized. Remnants of pyroxene rarely occur as phenocrysts. There are a number of fragments with a trachytic structure present.

The groundmass was originally glassy, but has been completely devitrified with, however, preservation of the original flow-structure and glassy structures.[5] The abundant feldspar of the groundmass has about the composition of oligoclase. Quartz is present to a slight extent. Apatite, rutile, ilmenite altered to leucoxene and abundant chlorite are present.

AUGITE BASALT PORPHYRY F-113

DISTRIBUTION: Specimens of augite basalt porphyry were taken from the vicinity of Spring Street, Stoneham, near the Wakefield line. Nothing is known of the relation of this basalt to the altered basalt of the High Rock area.

MEGASCOPIC: Dark greenish gray, porphyritic rock with large green black pyroxene phenocrysts in an aphanitic, lighter bluish gray groundmass. Specimens from one locality exhibit flow-structure to a very remarkable degree. Long slender phenocrysts, altered to hornblende, in parallel orientation mark the flow-structure.

MICROSCOPIC: The phenocrysts of augite are very perfectly idiomorphic and include large fragments of the groundmass and magnetite. Feldspar forms less abundant phenocrysts made up of a mosaic of feldspar anhedra altered to some extent to zeolites occuring as slender prismatic crystals often arranged in radiating aggregates. The groundmass is clouded by alteration products, chiefly of a limonitic nature, and consists of feldspar and augite dusted thoroughly with magnetite grains.

PEGMATITE F-200

DISTRIBUTION: The pegmatite has been found in considerable abundance cutting the hornblende alkali syenite in the vicinity of the golf links on the southern extremity of Bear Hill, on the border of the Towns of Wakefield, Stoneham and Reading. The pegmatite is also very abundant in drift. It is believed to become more abundant as the alkali syenite is approached.

MEGASCOPIC: The coarsest pegmatite observed consists of idiomorphic microcline, from 3 to 4 cm. in length, pure white albite (?) less perfectly developed, smaller amounts of black, roughly hexagonal, biotite plates, the largest being about 2 cm. in width, considerable quartz interstitially arranged between the feldspars, black hornblende, very limited in quantity, and numerous isometric garnets of a medium to dark red color.

ALKALI SYENITE F-201

DISTRIBUTION: A large portion of Wakefield is occupied by the southern extremity of the alkali syenite stock. The contact zone appears to be a zone of weakness and its topographical expression is characterized by rivers and lakes. The position of Lake Quannapowitt appears to have been determined by the contact zone.

MEGASCOPIC: The fresh rock is medium greenish gray of coarse grain. The related alkali syenite of Arlington Heights is light grayish green due to a smaller amount of hornblende and pyroxene. In Wakefield the outcrops are of light reddish yellow to dark reddish brown. The dark constituents break down much more rapidly than the feldspar producing a residual gravel or laterite characteristic in this area of the rock. The rock consists of feldspar, hornblende and a very small amount of quartz.

MICROSCOPIC: The minerals consist of albite-microcline microperthite, microcline, albite, albite-oligoclase, barkevikite, hedenbergite, aegirite, augite, quartz and iron ore. In a slide from altered material the hornblende and especially the hedenbergite, were nearly completely altered with development of limonite. The feldspar was remarkably fresh. The alteration has produced aggregates of ferro-anthophyllite fibers.[7]

SHEARED DIABASE F-111

DISTRIBUTION: The sheared diabase occurs as apophyses from a diabase dike near the Rattan Factory on Water Street. The field relations are described under structural geology.

MEGASCOPIC: Dark greenish gray rock with parallel streaks of the dark constituent.

MICROSCOPIC: Fine grained mixture of a bout equal parts of hornblende and feldspar with a highly schistose texture. The hornblende is more or less aggregated forming streaks or bands often very distinct. The section has numerous parallel fractures and a large fissure filled with feldspar and streaks of limonite crossing at right angles to the direction of schistosity.

Hornblende: Common hornblende pleochroic in green tones with, commonly, a decided blue case due, probably, to the presence of glaucophane molecule. It is the most abundant constituent and occurs elongated in the direction of schistosity. The other minerals are abundant titaniferous magnetite and secondary titanite.

STRUCTURAL GEOLOGY:

The Westboro quartzites and "hornfels" occur as roof pendants or xenoliths in the Dedham granodiorite porphyry and in the later alkali syenite.

The Marlboro formation, consisting chiefly of altered basalts are stated to occur interbedded with members of the Westboro formation in other areas. Their mutual relations could not be obtained in this area. There is an intrusive contact between the Marlboro basalts and the later Dedham granodiorite.

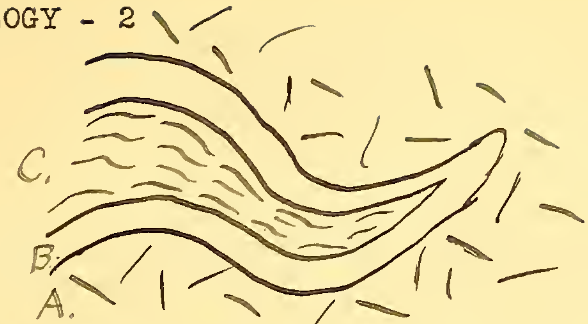
The Dedham granodiorite and Salem gabbro-diorite are members of a large batholithic intrusion extending between New Brunswick and Buzzards Bay. A zone of a fraction of a mile occurs between the granodiorite and the gabbro-diorite in which veins and stringers of one cut the other. All parts of this area contained typical gabbro-diorite and "granite" and no transition was observed.

Quartz keratophyre, makes up the greater proportion of volcanics in this area and are here referred to as members of the Mattapan group. The keratophyre occurs in intrusive contact with a granite of the Dedham series. A fairly large mass of keratophyre occurs surrounded by granodiorite. It was evidently preserved by having flowed into, and filling, an erosional depression in the granodiorite.

Alkali syenite occurs as a large stock believed to occupy a somewhat larger area than has been maped. No actual contact between the syenite and the other rocks was observed, but something of the nature of the contact between the syenite and the granodiorite is believed to have been found. The syenite is cut by a network of large and small quartz veins as the granodiorite is approached. The quartz occurs as interlocking, imperfectly formed crystals. A zone occurs in the granodiorite, near the syenite, which possesses a schistose structure which, perhaps, has been developed by shearing stresses produced during the intrusion of the syenite.

A hornblende rich alkali syenite occurs in contact with granite believed to be a large xenolith of the granite type found north of Castle Rock and in Saugus. The granite shows evidence of having been effected to a considerable extent by the country rock. It is cut by feldspar and quartz veins and appears considerably crumpled. There are numerous pegmatite veins cutting the hornblende syenite.

Little attention was devoted to the numerous diabase dikes of the area. One dike of diabase occurring near the Rattan Factory on Water Street, however, deserves mention. A number of apophyses from the dike have been subjected to shear and possess contact zones as illustrated in the figure.



A represents the normal granite, B is a bleached zone a few inches wide, nearly white in color, and C is an apophysis in which the flow-structure of the dark constituents is very conspicuous.

FAULTING: No evidence was found of the existence of major faulting. Attention was directed to the two major faults referred to as the "Lynn" and "Wakefield" as mapped by Clapp.[2] The sharp boundary of the "Lynn fault" was found to possess an extremely irregular aspect with irregularities extending for a distance of nearly one quarter of a mile and the different rocks, on opposite sides of the so-called fault, were found in irruptive contact at one locality near Castle Rock.

The volcanic rock, quartz keratophyre, has been stated as occuring only east of a certain line, the so-called Wakefield fault, and the statement made that the east side must be the downthrown for this reason. The keratophyre is, however, very much in evidence west of this line or "fault."

TABLE OF FORMATIONS.

Pleistocene and Recent	Superficial deposits	Till and outwash materials
Triassic (?)	Newark Series (?)	Diabase dikes
	INTRUSIVE CONTACT	
	Alkali Syenite	
Early Carboniferous	Hornblende alkali syenite (?)	
	Mattapan volcanic complex	Quartz keratophers Agglomerates
	UNCONFORMITY	
Devonian (?)	Dedham Granodiorite	Granodiorite porphyry, Granite, Aplite.
	Salem gabbro-diorite	Gabbro-diorite
	INTRUSIVE CONTACT	
Cambrian or Pre-Cambrian (?)	Marlboro formation	Mostly altered basalts
	Westboro formation	Quartzite, "Hornfels"

HISTORICAL GEOLOGY

The Westboro quartzite and "hornfels" comprise the oldest known rocks from this area. This formation has been tentatively assigned to the pre-cambrian. Little is known concerning their igneous or sedimentary origin.

The Marlboro formation, consisting chiefly of metamorphic basalts, were next introduced during a period of considerable volcanic activity. A considerable thickness of flows with some explosive material were formed. This period was followed by a period of erosion.

A batholithic intrusion of a sub-alkaline magma, the most important event of this region, was then initiated. The period of this intrusion is believed to have taken place in the Devonion. The reasons for this belief follow as stated by Emerson;[1]

They are intruded into and include many masses of the Algonkian (?) rocks, are overlain in broad areas by the Carboniferous sedimentary and volcanic rocks and are at some places cut by the younger granites.

The Dedham granodiorite appears to be in eruptive contact with the rocks of the Newbury volcanic complex and hence, if so, is at least as young as Devonian (The Newbury volcanics contain a submarine lava-flow which has preserved fossils in shale of either late Silurian or early Devonian).

On the other hand, this granodiorite and some associated rocks had been deeply weathered before the earliest Carboniferous sedimentary and volcanic rocks were laid down upon it, and it is therefore at least as old as Devonian.

Similar granites in the Maritime Provinces of Canada cut early Devonian strata and were deformed before the deposition of Mississippian strata.

After an erosional interval, a new period of volcanic activity of an alkaline nature was initiated. In Wakefield the volcanic rock of this period consists chiefly of quartz keratophyre. Emerson gives the following reasons for assigning these flows to the Carboniferous.[1]

They are intruded into the Devonian (?) igneous rocks and the volcanics rest upon and include many fragments of those rocks. At some places plutonic rocks and the older part of the volcanic rocks are overlain by the Carboniferous sedimentary rocks, known as such from their fossils. The later volcanic rocks are interbedded with these sedimentary rocks. As the basal Carboniferous sediments are as old as basal Pennsylvanian or older, the plutonic rocks and part of the volcanic rocks are probably of Mississippian age and the rest of Pennsylvanian age.

The stock of Alkali syenite was intruded during this period.

The last igneous activity of this area is represented by numerous diabase dikes referred here, tentatively, to the Triassic. They are at least younger than late Carboniferous and the Triassic is locally known to have been a period of considerable igneous activity.

After the glacial erosion of the Pleistocene, a new period was initiated, the Recent, characterized by an entirely new system of stream erosion determined to a great extent by the attitude of the glacial accumulations.

GLOSSARY

1. MINERALS

Actinolite.	A light green calcium, magnesium, iron amphibole $3 Mg (Fe)O \cdot Ca O \cdot 4 SiO$
Aegirite.	A pyroxene $Na_2 O \cdot Fe_2 O_3 \cdot 4 Si O_2$
Albite.	Soda feldspar $Na_2 O, Al_2O_3 \cdot 6 Si O_2$
Albite-oligoclase.	A feldspar having a composition between albite and oligoclase.
Andesine.	A soda-lime feldspar with the composition around $Ab_3 An_2$ Ab= Albite An= $Ca Al_2 Si_2 O_8$
Apatite.	A calcium phosphate containing a little fluorine or chlorine.
Augite.	A calcium magnesium silicate with iron aluminium, etc. A member of the pyroxene group.
Barkevikite	A soda-rich hornblende.
Biotite.	Magnesium, iron, aluminium silicate.
Chlorite.	A common mineral formed from minerals such as biotite. A magnesium aluminium silicate.
Epidote.	A common alteration product. A basic orthosilicate of calcium, aluminium and iron $H_2o \cdot 4Ca O \cdot 3(al, Fe)_2O_3 \cdot 6 Si O$
Feldspar.	A general name for a group of abundant rock-forming minerals. Albite, andesine, etc.
Ferro-anthophyllite.	A rare mineral first discovered by Dr. C. H. Warren of M. I. T. $(Fe, Ca, H_2 \cdot Mn) O \cdot Si O_2$ Received its name in 1921.
Garnet.	A group of silicate minerals used as gems and as abrasive. Almandite occurs in Wakefield and is an iron aluminium garnet.
Glaucophane.	An alkali-rich hornblende of light blue color $Na Al Si_2 O_6 \cdot (Fe, Mg) Si O_3$
Hornblende.	Common hornblende is a very common mineral. It is a calcium magnesium iron silicate with aluminium and sodium possessing a complex formula.

Ilmenite.	Iron titanium oxide. $Fe\,Ti\,O_3$
Iron Ore.	See Ilmenite and magnetite.
Kaolin.	The chief constituent of clay. A very abundant alteration product especially of the feldspars. $H_4\,Al_2\,Si_2\,O_9$ Hyrdous aluminium silicate.
Katophorite.	A little known soda-rich hornblende.
Labradorite.	A member of the feldspar group. About Ab An Ab = Albite An = Anorthite $Ca\,Al_2\,Si_2\,O_8$
Leucoxene.	An alteration product of ilmenite.
Limonite.	Brown iron ore. $2\,Fe_2\,O_3 \cdot H_2\,O$
Magnetite.	Magnetic iron ore $FeO \cdot Fe_2\,O_3$
Microcline.	A feldspar characterized by a striking cross-hatching structure in thin section. Its composition is the same as orthoclase, $K\,Al\,Si_3\,O_8$ but it crystallizes in a different system.
Microperthite.	A microscopic intergrowth of two feldspars usually albite and microcline.
Muscovite.	Common white mica $Al(Si\,O_4)_3\,K\,H_2\,Al_2$
Oligoclase.	A feldspar Ab_4 An etc. Ab= Albite An= Anorthite $Ca\,Al_2\,Si_2\,O_8$
Orthoclase.	Potassium feldspar $K\,Al\,Si_3\,O_8$
Pyrite.	Iron disulphide $Fe\,S_2$
Pyroxene.	A silicate family of which common augite is a member.
Quartz.	The most common mineral $Si\,O_2$
Rutile.	Titanium oxide $Ti\,O_2$ (Crystallized in the tetragonal system).
Sericite.	Practically fine aggregates of muscovite.
Titaniferous,	magnetite. Titanium bearing magnetite.
Titanite.	Sphene. Titanosilicate of calcium $Ca\,Ti\,SiO_5$
Zeolites.	A group of minerals practically hydrated feldspar.
Zircon.	Zirconium silicate $Zr\,Si\,O_4$

2. TECHNICAL TERMS

Some terms are defined in Part I.

α	Used to represent a direction through a mineral in which light is transmitted with the greatest ease. The fastest ray.
β	Represents intermediate ease of vibration.
γ	Represents the least ease of vibration.
Albite twinning law.	When two or more crystals intergrow according to some definite law the resulting group is said to be twinned. The albite law refers to a certain definate crystallographic plane on which the alternate parts of the twins have been rotated 180 degrees.
Amygdaloidal.	When pressure is relieved in rocks in the liquid state the contained gases are released puffing the rock forming cavities. It is these cavities later filled by mineral solutions that are known as amygdaloidal cavities.
Anhedra.	Grains of minerals without faces or crystal planes.
Aphanitic.	Having a texture so fine that the individual grains or crystals cannot be distinguished with the naked eye.
Basal section.	Refers to a section cut parallel to a crystallographic direction known as the base.
Batholith.	Huge irregular masses of rock which solidified in depth and have now become exposed by erosion.
Cleavage.	The tendency to split along definite directions. Appear as striations in thin sections.
Dike.	A long and thin body of rock which entered fissures in rocks during its fluid condition.
Extinction.	A direction is found in a mineral which appears dark when under crossed nicols and brought parallel to the vibration direction of either nicol. It can be readily seen that this position of darkness can be measured from cleavages, etc., with suitable apparatus.
Fault.	A fissure in rock along which there has been movement.

GLOSSARY- Continued

Graphic intergrowth.	Two minerals intergrown in such a way as to resemble Hebrew or cuneiform writing.
Groundmass.	The relatively fine portion of a rock containing larger crystals of coarser nature embedded, (phenocrysts).
Idiomorphic.	Possessing its own crystal outlines.
Maximum extinction.	The maximum value obtained for a given face between the position of darkness and cleavage or a similar feature.
Megascopic.	Features obtained with the naked eye or with small pocket lens.
Ophitic structure.	A structure characterized by well formed feldspar lath shaped crystals surrounded by later formed crystals of some other mineral commonly olivine or augite.
Optic normal.	A section at right angles to the direction of intermediate ease of light vibration in a mineral.
Orientation.	Determination of the relation of the directions of ether vibration to the crystallographic axes.
Phenocryst.	A relatively large crystal occuring in a finer groundmass. Phenocrysts are crystals of the earliest generation.
Pneumatolytic.	A general name applied to those minerals produced through the action of gases in igneous rocks.
Porphyritic.	A rock containing abundant or conspicuous phenocrysts is said to be porphyritic.
Refractive index.	A number which expresses the sine of the angle of incidence to the sine of the angle of refraction. Water = 1.336 Diamond = 2.270
Schistose.	Possessing a foliated or parallel structure as an ordinary schist.
Shearing.	The deformation of rocks produced by pressure producing schistosity, cleavage, minute plication and other metamorphic structures.
Trachytic.	A parallel structure of feldspar laths produced by the flow of a rock at the time of its origin.
Xenoliths.	Fragments of other rock or of an earlier solidified portion of the same mass inclosed in an igneous rock.

BIBLIOGRAPHY

I. Articles cited.

1. Emerson, B. K. Geology of Massachusetts and Rhode Island; U. S. Geol. Survey, Bull. 597, 1917.

2. Clapp, C. H. Geology of the igneous rocks of Essex County, Massachusetts: U. S. Geol. Survey Bull. 704, 1921.

3. Burbank, W. S. Geology of the region about Melrose, Massachusetts: manuscript thesis, Massachusetts Institute of Technology, 1911.

4. Lewis, J. Volney. Origin of pillow lavas: Geol. Soc. America Bull. Vol. 25, pp. 591-654, 1914.

5. Pirrson, L. V. The microscopical characters of volcanic tuffs: Am. Jour. Sci. Vol. XL, pp. 191-211, 1915.

6. Holmes, Arthur. Nomenclature of petrology: London, 1920.

7. Shannon, Earl V. Description of ferro-anthophyllite, an orthorhombic iron amphibole from Idaho, with a note on the nomenclature of the anthophyllite group. Proc. U. S. Nat. Mus. No. 2373, 1921.

II. General geology.

8. Pirsson, L. V., and Schuchert, Charles. Text-book of geology: Wiley & Sons, New York, 1920.

9. Grabau, Amadeus W. Text-book of geology: D. C. Heath & Co., New York, 1921.

10. Lahee, Frederic H. Field geology: McGraw-Hill, New York, 1916.

11. Lindgren, Waldemar. Mineral deposits: McGraw-Hill, New York, 1919.

III. Petrography.

12. Johannsen, Albert. Determination of rock-forming minerals: John Wiley & Sons, New York, 1918.

13. Winchell, N. H., and A. N. Elements of optical mineralogy: D. Van Nostrand Co., New York, 1909.

14. Weinschenk-Clark. Petrographic Methods: McGraw-Hill, New York, 1912.

15. Luquer, L. McI. Minerals in rock sections: D. Van Nostrand Co., New York, 1913.

16. Johannsen, Albert. Manual of petrographic methods: McGraw-Hill, New York, 1914.

17. Holmes, Arthur. Petrographic methods and calculations: Murby & Co., London, 1921.

18. Smith, H. G. Minerals and the microscope: Murby & Co., London, 1919. (Elementary)

19. Harker, Alfred. The natural history of igneous rocks: Macmillan, New York, 1909.

20. Iddings, J. P. Igneous rocks: John Wiley & Sons, New York, 1920.

21. Daly, R. A. Igneous rocks and their origin: Wiley & Sons 1914

22. Wright, F. E. The methods of petrographic-microscopic research: Carnegie Publications No. 158, Washington, 1911.

23. Sommers, R. E. Microscopic examination of clays: Jour. Wash. Acad. Sci., Vol. 9, No. 5, March 4, 1919.

24. Steidtmann, Edward. Feldspars as indicators of sedimentary or igneous origin of gneisses and schists: Geol. Soc. America Bull., Vol. 31, 1919.

25. Carlson, C. G. A test of the feldspar method for the determination of the origin of metamorphic rocks: Jour. Geo., Vol. 28, No. 7, October-November, 1920.

26. Warren, C. H. Petrology of the alkali-granites and porphyries of Quincy and the Blue Hills, Massachusetts, Proc. Am. Acad. Arts Sci., Vol. XLIX, No. 5, Sept. 1913.

27. Winchell, A. N. Rock classification on three co-ordinates: Jour. Geo., Vol 21, No. 3, April-May, 1913.

28. Miller, W. J. A classification of metamorphic rocks: Geol. Soc. Am. Bull., Vol. 28, pp. 451-462, 1917.

29. Daly, R. A. Average composition of igneous rock types: Proc. Am. Acad. Arts Sci., Vol. 45, p. 211, 1910.

IV. Mineralogy.

30. Ford, W. E. Dana's text-book of mineralogy: Wiley & Sons, New York, 1921.

31. Ford, W. E. Dana's manual of mineralogy: Wiley & Sons, New York, 1913.

32. Merrill, G. P. Handbook of gems and precious stones: U. S. Nat. Mus. Bull. 118, Washington, 1922. (Gratis)

33. Butler, G. M. Mineralogy, blowpipe analysis and crystallography: John Wiley & Sons, New York, 1918.

3a
248D

LUCIUS BEEBE MEMORIAL LIBRARY
3 1392 00357 6307